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XVIII. *An Account of some late fiery Meteors; with Observations. In a Letter from Charles Blagden, M. D. Physician to the Army, Sec. R. S. to Sir Joseph Banks, Bart. P. R. S.*

Read February 19, 1784.

TO SIR JOSEPH BANKS, BART. P. R. S.

DEAR SIR,

FROM the papers you were so good as to put into my hands, together with such other information as I could procure, the following account of the two most remarkable of the late meteors is collected. I am sensible, that it is in many respects very imperfect; yet still it gives a more satisfactory idea of the phænomena than can well be acquired from the relation of any single observer, and therefore may not be disagreeable to the learned Society over which you so worthily preside, if no more perfect account shall previously have been laid before them.

These meteors were of the kind known to the ancients by the names of *Λαμπαδες, Πιλοι*, Bolides, Faces, Globi, &c. from particular differences in their shape and appearance, and sometimes, I believe, under the general term of Comets*; in the
Philosophical

* ARISTOTLE's remark, that all the comets seen among them disappeared without setting, *Ἀπᾶντες οἱ καὶ ἡμᾶς ὁμῶντες (Κομήται) αὐτοὶ δυνστὶς ἡφανίσθησαν ἐν τῇ ὑπὲρ τῆς ὀριζήσεως τοῦ οὐρανοῦ* (Meteor. lib. I. c. 6.), seems scarcely applicable but to transitory meteors; and many other expressions to the same purpose occur in that author,

Philosophical Transactions they are called indiscriminately fire-balls or fiery meteors; and names of a similar import have been applied to them in the different languages of Europe.

The most material circumstances observed of such meteors may be brought under the following heads. 1. Their general appearance. 2. Their path. 3. Their shape or figure. 4. Their light and colours. 5. Their height. 6. Their noise. 7. Their size. 8. Their duration. 9. Their velocity.

I shall begin with the first of these meteors, that which was seen on the 18th of August.

§ 1. Its general appearance in these parts of Great Britain was that of a luminous ball, which rose in the N.N.W. nearly round, became elliptical and gradually assumed a tail as it ascended, and in a certain part of its course seemed to undergo a remarkable change compared to bursting; after which it proceeded no longer as an entire mass, but was apparently divided into a great number or a cluster of balls, some larger than the others, and all carrying a tail or leaving a train behind; under this form it continued its course with a nearly equable motion, dropping or casting off sparks, and yielding a prodigious light, which illuminated all objects to a surprising degree; till having passed the east, and verging considerably to the southward, it gradually descended, and at length was lost out of sight. The

PLINY, &c. SENECA himself, though he conceived distinctly enough the difference between comets and fiery meteors, yet evidently did not know where to draw the line (compare lib. I. and VII. *Quæst. Natur.*). Even in modern times, these meteors have struck spectators at first as comets (*Fritzes Medizinische Annalen*, vol. I. p. 77.); nay, expert astronomers, as appears by a letter from NATHANIEL PIGOTT, Esq. F. R. S. lately read before the Royal Society. See also *Mem. de l'Ac. des Scienc.* 1771, p. 688. I have insisted the more on a subject apparently of so little consequence, in order to account for the strange opinions of the ancients respecting comets, which, I think, proceeded chiefly from confounding them with these fiery meteors.

time

time of its appearance was 9 h. 16' P.M. mean time of the meridian of London, and it continued visible about half a minute.

§ 2. How far north the meteor may have begun I have no materials to determine with precision; but, as it was seen in Shetland, and at sea between the Lewes and Fort William, and appeared to persons at Aberdeen and Blair in Athol ascending from the northward, and to an observer in Edinburgh as rising like the planet Mars, there can be little doubt but its course commenced beyond the farthest extremity of this island, somewhere over the northern ocean. General MURRAY, F. R. S. being then at Athol House, saw it pass over his head as nearly vertical as he could judge, tracing it from about 45° of elevation north-north-westward to 30° or 20° south-south-eastward, where a range of buildings intercepted it from his view. From near the zenith of Athol House, it passed on a little westward of Perth, and probably a little eastward of Edinburgh; and continuing its progress over the south of Scotland, and the western parts of Northumberland and the Bishopric of Durham, proceeded almost through the middle of Yorkshire, leaving the capital of that county somewhat to the eastward. Hitherto its path was as nearly S.S.E. as can be ascertained; but somewhere near the borders of Yorkshire, or in Lincolnshire, it appears to have gradually deviated to the eastward, and in the course of that deviation to have suffered the remarkable change already noticed under the denomination of bursting. After this division, the compact cluster of smaller meteors seems to have moved for some time almost S.E. thus traversing Cambridgeshire and perhaps the western confines of Suffolk; but gradually recovering its original direction, it proceeded over Essex and the Straits of Dover, entering the continent probably not

far from Dunkirk, where, as well as at Calais and Ostend, it was thought to be vertical. Afterwards it was seen at Brussels, Paris, and Nuits in Burgundy *, still holding on its course to the southward; nay, I have met with an intimation, though of doubtful authority †, that it was perceived at Rome. Our information of its progress over the continent is, indeed, very defective and obscure; nevertheless, I think, we have sufficient proof that it traversed in all 13 or 14 degrees of latitude, describing a track of 1000 miles at least over the surface of the earth; a length of course far exceeding the utmost that has been hitherto ascertained of any similar phenomenon.

To adduce the different accounts from which this path is determined, would not only be insufferably tedious, but contrary to the intention of this letter, which is to give a summary view of the whole. They are contained partly in letters, and partly in the different news-papers of England and Scotland, most of which have been perused for this purpose. The information derived from the news-papers, however incorrect in the detail, is brought to some degree of certainty by the check of comparing them with one another; and their frequent publication in most places of consequence in this island, procures us advantages on the occasion of such extraordinary phenomena, not enjoyed in former ages, nor even now, to the like extent, in any other part of the world.

It seems scarcely more interesting to trace the path of these bodies with minute precision, than it would be to mark the progress of a cloud's shadow upon the ground; but it is of consequence to their theory to ascertain well the direction of their course; and their deviations from a straight line, as implying some particular cause, should be carefully noticed. I

* Journ. de Paris, Août 24, 1783.

† PARKER's General Advertiser, October 7, 1783.

have ventured to ascribe such a deviation to this meteor, from the concurrent testimony of many observers, who speak in the plainest terms of a manifest change in its course about the time it was seen to burst; and their evidence is confirmed by drawing a line S.S.E. from that part of Scotland to which the meteor was vertical, for such a line is found to correspond with its path as far as Yorkshire, but in the southern parts of the kingdom falls a great deal too much to the westward. That it afterwards resumed its former course is rendered probable from the testimony of the observers in Kent, who almost uniformly mention its disappearance in the S.S.E. as well as from the remarks made by several persons near the metropolis, that when it attained its greatest elevation, it bore but one or two points to the northward of east.

§ 3. This meteor was described by most spectators under three different forms, and is thus represented by Mr. SANDBY in his beautiful Drawing*; but the two first of those do not imply any real variation in its shape, depending only on a difference in the point of view. Accordingly, in the first part of its course over Scotland, it was seen to have a tail, and is thus described by General MURRAY when it passed Athol House. Two causes concur in this deception; first, the fore-shortening, and even occultation, of the tail, when the object is seen nearly in front; and, secondly, that the light of most part of the tail is of so inferior a kind, as to be difficultly perceived at a great distance, especially when the eye is dazzled by the overpowering brilliancy of the body. The length and shape of the tail, however, were perpetually varying; nor did the body continue always of the same magnitude and figure, but was sometimes round, at other times elliptical, with a blunt or

* Since engraved. See also the figures tab. IV. of this volume.

pointed protuberance behind. From such changes of figure in this and other meteors it is, that they have been compared to columns or pyramids of fire, comets, barrels, bottles, flasks, paper-kites, trumpets, tadpoles, glass-drops, quoits, torches, javelins, goats, and many similar objects; whence the multifarious appellations given to them by the ancients were borrowed.

Respecting the tails of meteors, it is here necessary to distinguish between two different parts of which they consist. The brightest portion seems to be of the same nature as the body, and indeed an elongation of the matter composing it; but the other, and that commonly the largest portion, might more properly be called the train, appearing to be a matter left behind after the meteor has passed; it is far less luminous than the former part, and often only of a dull or dusky red colour. A similar train or streak is not unfrequently left by one of the common falling stars, especially of the brighter sort; and vestiges of it sometimes remain for several minutes. It often happens, that even the large fire-balls have no other tail but this train, and ours of the 18th of August appeared at times to be in that state; its tail was likewise thought by some spectators to be spiral.

Under this changeable form, but still as a single body, it proceeded regularly till a certain period, when expanding with a great increase of light, it separated into a cluster of smaller bodies or ovals, each extended into a tail and producing a train. At the same time a great number of sparks appeared to issue from it in various directions, but mostly downward, some of which were so bright as also to leave a small train. Most fire-balls have suffered a bursting or explosion of this kind; but in general they have been thought to disappear immediately

afterwards. *This*, however, continued its course, becoming more compact, or perhaps re-uniting, and seems to have undergone other similar explosions before it left our island, and again upon the continent*. The different accounts tend to shew, that its first separation or bursting happened somewhere over Lincolnshire, perhaps near the commencement of the fens. Many observers did not get sight of it till after this period, and therefore never describe it as a single ball. There appears to be some deception, in consequence of which spectators are led to believe, that a meteor is extinguished by these explosions; for the same opinion was formed of this in several parts of this course, though we have such decisive evidence of its continued progress; whether it be that the meteors really become more dull for a time immediately after their explosion, or merely appear so on account of the greater preceding light, since they are always described as being most luminous the instant they burst.

It is observable, that the great change in this meteor corresponds with the period in which it suffered a deviation from its course, as if there was some connexion between those two circumstances; and there are traces of something of the same kind having happened to other meteors. If the explosion be any sort of effort, we cannot wonder that the body should be moved by it from a straight line; but on the other hand it seems equally probable, that if the meteor be forced, by any cause, to change its direction, the consequence should be, a division or separation of its parts.

§ 4. Nothing relative to these meteors strikes the beholders with so much astonishment as the excessive light they afford,

* For another instance of repeated explosions consult Mem. de l'Ac. des Scienc.
1756, p. 23.

sufficient to render very minute objects visible upon the ground in the darkest night, and larger ones to the distance of many miles from the eye. The illumination is often so great as totally to obliterate the stars, to make the moon look dull, and even to affect the spectators like the sun itself; nay, there are many instances in which such meteors have made a splendid appearance in full sun-shine. The colour of their light is various and changeable, but generally of a bluish cast, which makes it appear remarkably white. A curious effect of this was observed at Bruffels the 18th of August, that whilst the meteor was passing, "the moon appeared quite red, but soon recovered its natural light*." The brightness alone of the meteor is not sufficient to explain this, for the moon does not appear red when seen by day; but it must have depended on the the contrast of colour, and shews how large a proportion of blue rays enters into the composition of that light, which could make even the *silver* moon appear to have excess of red. Prismatic colours were also observed in the body, tail, and sparks of this meteor, variously by different persons; some compared them to the hues of gems. The moment of its greatest brightness seems to have been when it burst the first time; but it continued long to be more luminous after that period, than it was before.

The body of the fire-ball, even before it burst, did not appear of an uniform substance or brightness, but consisted of lucid and dull parts, which were perpetually changing their respective positions; so that the whole effect was to some eyes like an internal agitation or boiling of the matter, and to others like moving chasms or apertures. Similar expressions

* From a letter of the Abbé MANN's, Director of the Academy at Bruffels, to Sir JOSEPH BANKS, Bart. P. R. S.

have been used in the description of former meteors. The luminous substance was compared to burning brimstone or spirits, Chinese fire, the stars of a rocket, a pellucid ball or bubble of fire, liquid pearl, lightning and electrical fire; few persons fancied it to be solid, especially when it came near the zenith. Different spectators observed the light of the meteor to suffer at times a sudden diminution and revival, which produced an appearance as of successive inflammation; but might, in some cases at least, be owing to the interposition of small clouds in its path.

§ 5. When, in consequence of a more accurate attention to natural philosophy, such observations were first made upon fire-balls as determined their height, the computers were with reason surpris'd to find them moving in a region so far above that of the clouds and other familiar meteors of our atmosphere; especially as to every uninformed spectator they appear extremely near, or as if bursting over his head, a natural effect of their great light when seen without intervening objects. Their real height is to be collected from observations made at distant stations, which, for the greatest accuracy, ought to be so situated, that the line joining them may cut the path of the meteor at right-angles, and that, at its greatest elevation, it may appear from both of them about 45° above the horizon, on opposite sides of the zenith. Also two stations on the same side of its path, if the least angle of elevation be not very small, and the difference between that and the greatest angle be considerable, are by no means to be rejected. But little reliance can be placed upon observations of a meteor's altitude at any supposed period of its course, such as the moment of its bursting; because those changes are seldom so in-

stantaneous, or seen so much alike by different spectators, as to be marked with sufficient certainty.

Even in proper stations it rarely happens, that the angle of elevation can be observed with that degree of accuracy, which is necessary for any certain determination of the height. An estimate by the eye is doubtful, not only on account of the flattened curve the sky seems to describe, for which the most experienced observers scarcely ever make a just allowance, but likewise of the emotion produced by such an unexpected, magnificent, and perhaps alarming spectacle, which renders it almost impossible to be quite collected. Therefore, unless an observation be checked by means of a house, tree, or some fixed body, along which the meteor was found to range, it must be received as uncertain. By night the stars afford excellent marks, especially if the time be known with exactness; the brighter meteors, indeed, render these faint lights invisible for the moment, but here we derive an eminent advantage from the train, which remains after the meteor is gone, and delineates perfectly its track through the heavens. If no such marks have been taken, the expedient of endeavouring to recollect the part of the sky where it passed, and ascertaining that height with a quadrant, may often be useful; but there are many men of such a turn of mind, that the original impression made upon them will be totally perverted by their own subsequent reflexions and the remarks of others; in which case such an application of instruments is likely to give a result farther from the truth, than their first immediate judgement, however vague and hazarded.

I am sorry to add, that most of the observations in my possession of the meteor which appeared the 18th of August, give its altitude by estimation only; yet I hope their correspondence

with one another will gain them a degree of credit, to which, if single, they would not be entitled.

1. In a letter from Perth in Scotland it is said, that “a gentleman, who has a very good eye, observed the meteor pass about 6° to the westward of the zenith;” and a Professor in one of the Universities, being at Ardoch on the banks of the Tweed, about two miles below Dunbarton, judged it to have “at least 45° of elevation above the horizon.” These altitudes would make its real height 57 statute miles.

2. At St. Andrew’s in Scotland, “it was not quite vertical, but according to some was 20° or 25° from the zenith, according to others not so much.” Taking the greatest of these distances as nearest the truth, since we are usually led to estimate altitudes greater than they really are, this observation, calculated with that of Ardoch, gives 60 miles for the height.

For the communication of these observations, collected by his friends, I am indebted to General MELVILL F. R. S.

At Edinburgh the meteor passed very near the zenith, in which case a deviation of a few degrees is scarcely perceptible to a common eye.

The rev. Mr. WATSON of Whitby, in a letter to Lord MULGRAVE V. P. R. S. is very confident, that the greatest altitude of the meteor, which passed to the westward of his zenith, was 60° . Mr. EDGEWORTH F. R. S. in his letter to you, Sir, states its elevation at Edgeworth’s-Town near Mullingar, in Ireland, as 10° or 12° above the eastern horizon. These observations, calculated strictly from the latitudes and longitudes with the allowance for the curvature of the earth, as indeed were all the rest where the difference would be sensible, give 57 miles for the height of the meteor.

4. In the Morning Chronicle of Sept. 19. is inserted a letter from Newton Ardes, 7 miles east of Belfast, in Ireland, corresponding so well with Mr. EDGEWORTH's in the description of the meteor, as to appear very good authority. The altitude is there given as 16° , whence a height of 58 miles with the observation at Whitby.

5. Mr. MORE, Secretary to the Society for the encouragement of Arts, Manufactures, and Commerce, saw the meteor as he was riding about three miles S.W. of Broseley in Shropshire, and judged it to be elevated 35° . By a perpendicular drawn from this spot to its supposed path in Lincolnshire, its height came out 59 miles.

6. The altitude of 25° determined at Windsor I take to be one of those on which most reliance can be placed, because the gentlemen present, two of them Fellows of the Royal Society, were remarkably well qualified for such an estimation. The letter you received, Sir, from Professor ALLAMAND of Leyden, mentions that the meteor was seen there about 30° above the horizon, and the terms in which it is described in the Dutch news-papers * agree with this account. Its height hence calculated appears to be 58 miles.

7. Mr. THOMAS SQUIRE, of Folkestone, observed the meteor over his house, as he was in the posture of leaning back against a hedge; he afterwards tried "its ranging with the roof by a "quadrant, and found it $68^{\circ}\frac{1}{2}$ above the horizon." Reducing this observation to the perpendicular dropped from Windsor on the path of the meteor, its height comes out 54 or 55 miles. Mr. SQUIRE's altitude, determined by a fixed object, is confirmed by the estimate of several persons at Ramsgate.

* *Amsterdamsche Courant*, Aug. 28, 1783.

8. The meteor was seen by Mr. STEEVENS F. R. S. at Hampstead near London, moving along over the top of a row of trees. Mr. CAVENDISH F. R. S. having taken the altitude of these trees with a quadrant, found that of the highest, as seen from the part of the garden-walk opposite to it, to be 33° ; which corresponds very well with the other observations, and consequently gives the same height for the meteor. Mr. STEEVENS kept his eye upon it constantly, whilst he passed briskly along the walk.

This agreement of the different altitudes is nearer than could be expected; yet I know of no contradictory observations of any authority, except some made near Plymouth and in Cornwall, where the meteor being pretty near the horizon, its altitude, as will commonly happen in such cases, is given too great. The effect of this, however, would be to shew, that the meteor was higher; and therefore, I think, we may safely conclude, that it must have been more than 50 miles above the surface of the earth, in a region where the air is at least 30000 times rarer than here below.

Contrary to what has been asserted of most other fire-balls, this of the 18th of August appears by the preceding observations to have kept on in a parallel course, without any descent or approach toward the earth. It may be much questioned, whether such a descent has been proved in any former instance. The meteor described by Sir JOHN PRINGLE has been cited as the most certain example; but any person who carefully examines the observations themselves, as stated in the 51st volume of the Philosophical Transactions, will find them totally inadequate for such a conclusion; its height seems to me determined only in one part of its course, between Island-Bridge
and

and Ancram, and was there from 48 to 50 miles *. M. LE ROY supposes the fire-ball seen July 17, 1771, to have been 54 miles high when it began, and 27 at its explosion †; but does not give the facts on which his calculation is founded.

Every philosopher must be struck with the agreement of these meteors in their distance from the earth, just beyond the limits of our crepuscular atmosphere.

§ 6. That a report was heard some time after the meteor of the 18th of August had disappeared, is a fact which rests upon the testimony of too many witnesses to be controverted, and is, besides, conformable to what has been observed in most other instances. In general it was compared to the falling of some heavy body in a room above stairs, or to the discharge of one or more large cannon at a distance. That rattling noise, like a volley of small arms, which has been remarked after other meteors, does not seem to have been heard on this occasion. From a comparison of the different accounts, it appears as if the report was loudest in Lincolnshire and the adjacent countries, and again in the eastern parts of Kent; in the intermediate places it was so indistinct as generally not to have been noticed, and all observers of credit in Scotland deny that they heard any thing of the sort. If, therefore, this report be connected with the bursting of the meteor, I should be inclined to suppose, that sound was produced two separate times, namely at the first explosion over Lincolnshire, and again when it seemed to burst soon after entering the continent. Ingenious men have availed themselves of this sound, to calculate the distance and height of meteors; and the exactness attained by this method, in the computation of the late fire-ball from the report heard at

* Phil. Transf. vol. LI. p. 241. and 274.

† Mem. de l' Acad. des Scienc. 1771, p. 676.

Windsor*, is very remarkable ; but in general the accounts disagreed so much, that it would have been impossible to conclude any thing from them. Perhaps too the method itself is less certain than has been thought ; for as the propagation of sound, and with intensity too, in air rarefied 30000 times, presents great difficulties in theory, though it may be in some measure explicable from the vast bulk of the meteor, and the large quantity of this rare air it may therefore displace by a sudden expansion ; I think it not improbable, that some hitherto unperceived circumstance comes into play, by which the whole effect may be modified : for instance, if matter belonging to the meteor itself be what conveys the sound to our lower atmosphere, it may either admit sound to be propagated through it at a different rate than through common air, or it may move much faster than sound travels, as the entire meteor certainly does, and carry on the sonoric vibrations with it. Moreover, we cannot be sure what is the velocity of sound in air so much rarer than where our experiments have been made. For these reasons, while we distrust calculations of meteors founded on the progress of sound, we should be particularly careful to note down the intervals, and all the circumstances, as they may lead to very curious discoveries. The effect of the noise is, frequently, to produce such a shaking of the doors, windows, and the whole house, as is mistaken for an earthquake.

Besides the report as of explosions which was heard *after* the meteor, another sort of sound was said to *attend* it, more doubtful in its nature, and less established by evidence ; I mean, a kind of hissing, whizzing, or crackling, as it passed along. That sound should be conveyed to us in an instant from a body above 50 miles distant, appears so irreconcilable to all we know of philosophy, that perhaps we should be justified in

* See p. 111. of this volume.

imputing the whole to an affrighted imagination, or an illusion produced by the fancied analogy of fireworks. The testimony in support of it is, however, so considerable, on the occasion of this as well as former meteors, that I cannot venture to reject it, however improbable it may be thought, but would leave it as a point to be cleared up by future observers.

§ 7. To determine the bulk of the fire-ball, we must not only have calculated its distance, but also know the angle under which it appeared. For this purpose the moon is the usual term of comparison; but as it was thought, at very different distances, to present a disk equal to that luminary's, and the same expressions have been applied to most preceding fire-balls, I conceive this estimation rather to be a general effect of the strong impression produced by such splendid objects on the mind, than to convey any determinate idea of their size. However, if we suppose its transverse diameter to have subtended an angle of $30'$ when it passed over the zenith, which probably is not very wide of the truth, and that it was 50 miles high, it must have been almost half a mile across. The tail sometimes appeared 10 or 12 times longer than the body; but most of this was train, and the real elongation behind seems seldom to have exceeded twice or thrice its transverse diameter, consequently was between one and two miles long. Now if the cubical contents be considered, for it appeared equally round and full in all directions, such an enormous mass, moving with extreme velocity, affords just matter of astonishment.

§ 8. The duration of the meteor is very differently stated, partly because some observers had it in view a much longer time than others, and partly because they formed different judgements of the time. Those who saw least of it seem to have perceived its illumination about ten seconds, and those
who

who saw most of it about a minute: hence the various accounts may in some measure be reconciled. Mr. HERSCHEL F. R. S. at Windsor, must have kept it in sight long after other observers had thought it extinct: for though, probably, he did not see the beginning, as it never appeared to him like a single ball, he watched it as much as “forty or forty-five” seconds, the last twenty or twenty-five of which it remained “almost in one situation, within a few degrees of the horizon.” This confirms the foreign accounts of its long progress to the southward.

As scarcely any one had sufficient presence of mind to minute the time by his watch, the periods given for its duration are mostly by guess. To correct this rude conjecture, it has been proposed, that the observer should endeavour to pass over the time in his own mind as well as he can by recollection, whilst another person silently marks the seconds with a watch. This may do something, but still leaves the matter very uncertain, as the nature of the emotion felt by the spectator while it was passing will cause the impression of a longer or shorter time to be left upon his mind; and the formal process of recollection is so tedious, that I believe the duration will in this way generally be made too short. Mr. HERSCHEL, at my request, was so good as to act over his observation, with the positions and gestures he was obliged to employ; and this seems likely to come nearer the truth than a simple effort of the mind at recollection. But the surest method would be, to repeat any uniform action in which the spectator might have been engaged at the time; as, for instance, to walk over the same space of ground, that he passed while the meteor was in sight.

§ 9. From the apparent motion of the meteor, compared with its height, some computation may be formed of its astonishing

velocity. As at the height of 50 miles above the surface of the earth, it might be visible from the same station for a tract of more than 1200 miles, and the longest continuance of its illumination scarcely exceeded a minute, we have hence some presumption that it moved not less than 20 miles in a second. The rev. Mr. WATSON, in his letter to Lord MULGRAVE, says, *that the arc described by it whilst in his view could not be less than 70° or 80° , and yet the time could not exceed $4''$ or $5''$ at most.* This, with an altitude of 60° , and height of 50 miles, gives for its velocity about 21 miles in a second. The observer at Newton Ardes estimated its motion to be 10° in a second, at the altitude of 16° ; this would make its velocity 30 miles in a second. Mr. HERSCHEL found it describe an arch of 167° during the 40 or 45 seconds he observed it, which gives a velocity of more than 20 miles in a second. Finally, Mr. AUBERT F. R. S. thought it described an arch of 136° of azimuth in 10 or 12 seconds, which would make its velocity above 40 miles in a second. I am sensible of the objections that may be made to all these computations; undoubtedly they are too vague; and yet, all taken together, perhaps they may have some weight, especially as they correspond so well with the different phenomena of the meteor's duration, and other fire-balls have been computed to move as fast*. Stating the velocity at the lowest computation of 20 miles a second, it exceeds that of sound above 90 times, and begins to approach toward that of the earth in her annual orbit. At such a rate, it must have passed over the whole island of Great Britain in less than half a minute, and might have reached Rome within a minute

* See Mem. de l'Acad. des Scienc. 1771, p. 678. Phil. Trans. N^o 341. and 360. and vol. LI. p. 263, &c.

afterwards, or in seven minutes have traversed the whole diameter of the earth !

From this calculation it will be evident, that there is little chance of determining the velocity of meteors from the times of their passing the zenith of different places ; and that therefore we must principally depend on observing carefully, with a watch that shews seconds, their apparent velocity through the heavens.

THE fire-ball which appeared on the 4th of October, at 43 past six in the evening, was much smaller than that already described, and of much shorter duration. It was first perceived to the northward as a stream of fire, like the common shooting stars, but large ; and having proceeded some way under this form, it suddenly burst out into that intensely bright bluish light which is peculiar to such meteors. At this period I saw it, and can compare the colour to nothing I am acquainted with so well, as to the blue lights of India, and some of the largest electrical sparks. The illumination was very great ; and on that part of its course where it had been so bright, a dusky red streak or train was left, which remained visible perhaps a minute even with a candle in the room, and was thought by some gradually to change its form. Except this train, I think the meteor had no tail, but was nearly a round body, or perhaps a little elliptical. After moving not less than 10° in this bright state, it became suddenly extinct, without any appearance of bursting or explosion.

This meteor was seen for so short a way, that it is scarcely possible to determine the direction of its course with accuracy ; but as in proceeding to the eastward it very perceptibly inclined towards the horizon, it certainly moved somewhere from the north-westward to the south-eastward. Its duration was so

short, that many persons thought it passed in an opposite direction; for my own part, I found myself absolutely unable to determine whether the motion was *from* or *toward* the S.E. Some spectators were of opinion, that it changed its course the moment it became bright, proceeding no longer in the same straight line; but my information is not sufficient to determine this question.

My situation, Sir, was particularly fortunate for ascertaining the height of this meteor, as I saw it from your Library, ranging immediately over the opposite roof of your house. Hence I find by a quadrant that its altitude, even when it became extinct, could not be less than 32° . The upper northernmost end of the train it left bore, as I judge by the compass, about 28° northward of true E. and the lower end about 14° . I have only one observation to compare with this, which was made by Mr. Boys of Sandwich. He concludes, from the train I imagine, that "it disappeared just under, and a very "little to the westward" (rather northward) "of, the star γ in the foot of Cepheus." At that time γ Cephei was about 57° high, and bore above 21° to the eastward of N. whence the height of the meteor above the surface of the earth, after all proper allowances are made*, must have been between 40 and 50 miles.

As there was no appearance of bursting at the extinction of this fire-ball, so no report was heard after it; nor did any sound attend it.

Some observers thought *this* meteor also near as big as the moon, but to me it did not appear above one quarter of her diameter, which would make its breadth somewhat above a furlong.

* It appears from observations taken by Gen. Roy, F. R. S. that the bearing of Sandwich from London is not so much to the southward of east, as it is laid down in our maps.

If the whole of the meteor's track be included, it seems to have lasted as much as three seconds, but in the bright state its duration was less than two, I think not much above one. Supposing it described an arc of 14° in $1\frac{1}{2}$ second, or, according to Mr. AUBERT's observation, of 25° in $3''$, its real velocity was about 12 miles a second.

Such meteors as these, which pass like a flash of lightning, and describe so short a course, are very unfavourable for calculating the velocity, but afford great advantages for determining the height, as they must be seen nearly at the same moment and in the same place by the different observers. Other instances are found of fire-balls beginning with a dull red light like a falling star, particularly the great one of March 19, 1719, treated of so fully by Dr. HALLEY * and Mr. WHISTON †.

It is remarkable, that a similar meteor had appeared the same day, that is, Saturday the 4th of October, about three in the morning, though, on account of the early hour, it was seen by fewer spectators. They represent it as rising from the northward to a small altitude, and then becoming stationary with a vibratory motion, and an illumination like day-light; it vanished in a few moments, leaving a train behind. This sort of tremulous appearance has been noticed in other meteors, as well as their continuing stationary for some time, either before they began to shoot forward, or after their course was ended.

* Phil. Transf. vol. XXX. N^o 350. p. 978.

†. Account of a surprising meteor seen March 19, 1719.

I FIND it, Sir, impossible to quit this subject, without some reflexions about the cause, that can be capable of producing such appearances at an elevation above the earth, where, if the atmosphere cannot absolutely be said to have ceased, it is certainly to be considered as next to nothing. The first idea which suggested itself, that they were burning bodies projected with such a velocity, was quickly abandoned, from the want of any known power to raise them up to that great height, or, if there, to give them the required impetus; and the ingenuity of Dr. HALLEY soon furnished him with another hypothesis, in which he thought both these difficulties obviated. He supposes there is no projection of a single body in the case; but that a train of combustible vapours, accumulated in those lofty regions, is suddenly set on fire, whence all the phænomena are produced by the successive inflammation *. But Dr. HALLEY gives no just explanation of the nature of these vapours, nor of the manner in which they can be raised up through air so extremely rare; nor, supposing them so raised, does he account for their regular arrangement in a straight and equable line of such prodigious extent, or for their continuing to burn in such highly rarefied air. Indeed, it is very difficult to conceive, how vapours could be prevented, in those regions where there is in a manner no pressure, from spreading out on all sides in consequence of their natural elasticity, and instantly losing that degree of density which seems necessary for inflammation. Besides, it is to be expected, that such trains would sometimes take fire in the middle, and so present the phænomenon of two meteors at the same time, receding from one another in a direct line.

These difficulties have induced other philosophers to relinquish Dr. HALLEY's hypothesis, and propose, instead of it,

* Phil. Trans. vol. XXX. N^o 360.

one of a very opposite nature, that meteors are permanent solid bodies, not raised up from the earth, but revolving round it in very eccentric orbits; or, in other words, that they are terrestrial comets*. The objections to this opinion, however, seem to me equally great. Most observers describe the meteors, not as looking like solid bodies, but rather like a fine luminous matter, perpetually changing its shape and appearance. Of this many defenders of the opinion are so sensible, that they suppose the revolving body gets a coat or atmosphere of electricity, by means of which it becomes luminous; but, I think, whoever carefully peruses the various accounts of fire-balls, and especially ours of the 18th of August when it divided, will perceive that their phænomena do not correspond with the idea of a solid nucleus enveloped in a subtile fluid, any more than with the conjecture of another learned gentleman, that they become luminous by means of a contained fluid, which occasionally explodes through the thick solid outer shell †.

A strong objection to this hypothesis of permanent revolving bodies, is derived from the great number of them there must be to answer all the appearances. Such a regular gradation is observed, from those large meteors which strike all beholders with astonishment, and occur but rarely, down to the minute fires called shooting stars, which are seen without being regarded in great numbers every clear night, that it seems impossible to draw any line of distinction between them, or deny that they are all of the same nature. But such a crowd of revolving bodies could scarcely fail to announce their existence by some other means than merely a luminous train in the night;

* See a dissertation on this subject by Professor CLAP, of Yale College, New England.

† Phil. Trans. vol. L.I. p. 267.

as, for instance, by meeting or justling sometimes near the earth, or by falling to the earth in consequence of various accidents; at least we might expect they would be seen in the day-time, either with the naked eye of telescopes, by some of the numerous observers who are constantly examining the heavens. With regard to these falling stars, it were much to be wished, that observations should be made upon them by different persons in concert at distant stations, for the purpose of ascertaining their height and velocity; which would tend very much to illustrate all this part of meteorology.

Another argument of great weight against the hypothesis that fire-balls are terrestrial comets, is taken from their great velocity. A body falling from infinite space toward the earth, would have acquired a velocity of no more than 7 miles a second, when it came within 50 miles of the earth's surface; whereas these meteors seem to move at least three times faster. And this objection, if there be no mistake in regard to the velocity of the meteors, as I think there is not, absolutely overthrows the whole hypothesis.

What then can these meteors be? The only agent in nature with which we are acquainted, that seems capable of producing such phænomena, is electricity. I do not mean that by what is already known of that fluid, all the difficulties relative to meteors can be solved, as the laws, by which its motions on a large scale are regulated in those regions so nearly empty of air, can scarcely, I imagine, be investigated in our small experiments with exhausted vessels*; but only that several of the facts point out a near connexion and analogy with electricity, and that none of them are irreconcilable to the discovered laws of that fluid.

* How nearly the phænomena of meteors have been represented by artificial electricity is known from a very remarkable experiment of Mr. ARDEN's. See PRIESTLEY, vol. V. p. 379.

1. Electricity moves with such a prodigious velocity, as to elude all the attempts hitherto made by philosophers to detect it; but the swiftness of meteors, stating it at 20 miles a second, is such as no experiments yet contrived could have discovered, and which seems to belong to electricity alone. This is, perhaps, the only case in which the course or direction of that fluid is rendered perceptible to our senses, in consequence of the large scale on which these fire-balls move.

2. Various electrical phenomena have been seen attending meteors. Lambent flames are described as settling upon men, horses, and other objects*; and sparks coming from them, or the whole meteor itself, it is said, have damaged ships, houses, &c. in the manner of lightning†. These facts, I must own, are but obscurely related, yet still they do not seem to be destitute of foundation. If there be really any hissing noise heard while meteors are passing, it seems explicable on no other supposition than that of streams of electric matter issuing from them, and reaching the earth with a velocity equal to that of the meteor, namely, in two or three seconds. Accordingly, in one of our late meteors, the hissing was compared to that of electricity issuing from a conductor‡. The sparks flying off so perpetually

* PRIESTLEY's History of Electricity, p. 352. Mem. de l'Acad. des Scienc. 1771, p. 681, 682. See an odd fact, perhaps of this nature, in PARKER's General Advertiser, Dec. 1, 1783.

† Mem. anc. de l'Acad. de Dijon, tom. I. Hist. p. 42. Phil. Trans. vol. XLVI, p. 366. Hist. de l'Acad. des Scienc. 1761, p. 28.

‡ Chester Weekly Courant, August 26, 1783. This and many other curious circumstances, relative to meteors, are so well exemplified in the following observation, made several years ago by Mr. ROBINSON at Hinckley in Leicestershire, that I think it worth transcribing here, especially as it occurs in a work which few people would think of consulting on such a subject. "Oct. 26, 1766, at half past five in the evening, after a violent storm of wind and rain, Vol. LXXIV. G g " I

perpetually from the body of fire-balls, may possibly have some connexion with these streams *. In the same manner the sound of explosions may perhaps be brought to us quicker, than if it were propagated through the whole distance by air alone. Should these ideas be well founded, the change of direction which meteors seem at times to undergo, may possibly be influenced by the state of the surface of the earth over which

“ I observed a fiery meteor. Its direction was from N.W. to S.E. nearly in a horizontal direction; it passed very near to me, and was of an elliptical form; its motion about 40° in 2'' or 3'' of time. It was very bright and lucid to appearance like the palest lightning, and emitted sparks continually, which formed a kind of tail toward the N.W. which seemed to be extinguished at the distance of 2° or 3° from the body; there was a small portion that parted from it. The cohesion of matter was so great, that it drew a thread of considerable length from the body, before it broke from it. During the passage there was a kind of hissing noise, much like to what we hear from the electrical machine when the electric matter is running away, or as when it is escaping from a full charged jar.” *Bibliotheca Topographica Britannica*, N^o VII. p. 81.

* *Hist. de l'Acad. des Scienc.* 1761, p. 28. *Mem. de l'Acad. des Scienc.* 1771, p. 682. Extract of a letter from the Abbé MANN, Director of the Academy at Brussels, to Sir JOSEPH BANKS, Bart. P. R. S. “ I shall only mention one singular circumstance, which was communicated to me by a particular friend of mine. It happened at Mariekercke, a small village on the coast, about half a league to the W. of Ostend. The curate of the village was sitting in the dusk of the evening with a friend, when a sudden light surprised them, and immediately after a small ball of light-coloured flame came through a broken pane of glass, crossed the room where they were sitting, and fixed itself on the chink of a door opposite to the window where it entered, and there died gradually away. It appeared to be a kind of phosphoric light, carried along by the current of air. The curate and his friend, greatly surprised at what they saw, apprehended fire in the neighbourhood; but going out, found that the fire, which had come in through the window, had been detached from a large meteor in its passage.”

How far these and similar appearances may be owing simply to the illumination produced by meteors, should be attentively considered in the investigation of such facts.

they are passing, and to which the streams are supposed to reach. A similar cause may occasion the apparent explosion, the opening of more channels giving new vent and motion to the electric fluid. May not the deviation and explosion which appear to have taken place in the fire-ball of the 18th of August over Lincolnshire, have been determined by its approach toward the fens, and an attraction produced by that large body of moisture?

3. A further argument for the electric origin of meteors is deduced from their connexion with the northern lights, and the resemblance they bear to these electrical phenomena, as they are now almost universally allowed to be, in several particulars. Instances are recorded, where northern lights have been seen to join and form luminous balls, darting about with great velocity, and even leaving a train behind like the common fire-balls*. This train I take to be nothing but the rare air left in such a highly electrified state as to be luminous; and some streams of the northern lights are very much like it. The *aurora borealis* appears to occupy as high, if not a higher, region above the surface of the earth, as may be judged from the very distant countries to which it has been visible at the same time†; indeed the great accumulation of electric matter seems to lie beyond the verge of our atmosphere, as estimated by the cessation of twilight. Also with the northern

* Hist. de l'Acad. des Scienc. 1705, p. 35. WHISTON'S Account of a Meteor seen in the Air 1718. Phil. Transf. vol. XII. p. 626; and LIII. p. 6? Also a most pointed fact in the Act. Liter. Sueciæ, 1734, p. 78.

† BERGMAN, upon a mean of 30 computations, makes the average height of the northern lights to be near 70 Swedish, that is, about 460 English miles. Kong. Vetensk. Acad. Handlingar, vol. XXV. p. 193. See also Phil. Transf. vol. LIV. p. 327. and M. DE MAIRAN'S *Traité de l'Aurore Boreale*, p. 51.

lights a hissing noise is said to be heard in some very cold climates; GMELIN speaks of it in the most pointed terms, as frequent and very loud in the north-eastern parts of Siberia*; and other travellers have related similar facts †.

But,

* *Reise durch Siberien*, vol. III. p. 135. As the whole passage is very remarkable, and has never, that I know, appeared in English, I thought the following translation of it might be acceptable.

“ These northern lights begin with single bright pillars, rising in the N. and almost at the same time in the N.E. which gradually increasing comprehend a large space of the heavens, rush about from place to place with incredible velocity, and finally almost cover the whole sky up to the zenith. The streams are then seen meeting together in the zenith, and produce an appearance as if a vast tent was expanded in the heavens, glittering with gold, rubies, and sap-phire. A more beautiful spectacle cannot be painted; but whoever should see such a northern light for the first time, could not behold it without terror. For however fine the illumination may be, it is attended, as I have learned from the relation of many persons, with such a hissing, cracking, and rushing noise throughout the air, as if the largest fire-works were playing off. To describe what they then hear, they make use of the expression, *Spolochi chodjat*, that is, the raging host is passing. The hunters who pursue the white and blue foxes in the confines of the Icy Sea, are often overtaken in their course by these northern lights. Their dogs are then so much frightened, that they will not move, but lie obstinately on the ground till the noise has passed. Commonly clear and calm weather follows this kind of northern lights. I have heard this account, not from one person only, but confirmed by the uniform testimony of many, who have spent part of several years in these very northern regions, and inhabited different countries from the Yenisei to the Lena; so that no doubt of its truth can remain. This seems indeed to be the real birth-place of the *aurora borealis*.”

It is here to be observed, that GMELIN did not collect the account himself, but extracted it from letters or papers of M. DE L'ISLE DE LA CROYERE's, who was himself far to the northward of Yakutsk, without hearing these noises; probably, therefore, it is much exaggerated, though one can scarcely suppose the whole to be fabulous.

† *Muschenbroeck Introduct.* § 2495. *Beccaria dell' Elettricismo artif. et nat.*

But, in my opinion, the most remarkable analogy of all, and that which tends most to elucidate the origin of these meteors, is the direction of their course, which seems, in the very large ones at least, to be constantly from or toward the north or north-west quarter of the heavens, and indeed to approach very nearly to the present magnetical meridian. This is particularly observable in those meteors of late years whose tracks have been ascertained with most exactness; as that of November 26, 1758, described by Sir JOHN PRINGLE; that of July 17, 1771, treated of by M. LE ROY; and this of the 18th of last August. The largest proportion of the other accounts of meteors confirm the same observation, even those of a more early period*; nay, I think, some traces of it are per-

p. 221. There is now working with Mr. NAIRNE F. R. S. a person of the name of ARNOLD, who resided seven years at Hudson's Bay, the last three at Fort Henley. He confirms M. GMELIN's account of the fine appearance and brilliant colours of the northern lights, and particularly of their rushing noise, which he affirms he has very frequently heard, and compares it to the sound produced by whirling round a stick swiftly at the end of a string. He adds, that on conversing about this matter with a Swedish watch-maker of the name of LIND, that person assured him, that he had heard a similar noise in his own country. Mr. NAIRNE too, one time, at Northampton, when the northern lights were remarkably bright, is confident he perceived a hissing or whizzing sound.

This hissing or rushing noise, as well as that attending meteors in their passage, supposing it in both cases to be real, I would attribute to small streams of electric matter, running off to the earth from the great masses or accumulations of electricity, by which I suppose both meteors and the northern lights to be produced. Compare M. DE MAIRAN's *Traité de l'Aurore Boréale*, p. 126.

* See Phil. Transf. and Mem. de l'Acad. des Sciences, &c. I have found, of an earlier or later period, accounts of more than 40 different fire-balls. Of these above 25 are so described, that it is certain their course was in the above-mentioned direction; only 3 or 4 seem to have moved the contrary way; and with regard to the remainder, it is left doubtful, from the imperfect state of the relations,

perceivable in the writings of the ancients*. Whether their motion shall be *from* the northern quarter of the heavens or *toward* it, seems nearly indifferent, as the numbers of those going each way are not very unequal; I consider them, in the former case, as masses of the electric fluid repelled, or bursting from the great collected body of it in the north; and, in the latter case, as masses attracted toward that accumulation; a distinction, probably, much the same in effect, as that of positive and negative electricity near the surface of the earth.

This tendency toward the magnetic meridian, however, seems to hold good only with regard to the largest sort of fireballs; the smaller ones move more irregularly, perhaps because they come further within the verge of our atmosphere, and are thereby more exposed to the action of extraneous causes. That the smaller sort of meteors, such as shooting stars, are really lower down in the atmosphere, is rendered very probable by their swifter *apparent* motion; perhaps it is this very circumstance which occasions them to be smaller, the electric

tions. When we consider that even the meteor of the 18th of August last was thought by *some* spectators to move south-westward, it will rather appear surprising that so many of these accounts should correspond, than that a few of them should differ.

* ARISTOTLE (Meteor. lib. I. c. 6.) denies that comets, with which I take meteors to be confounded, are generated *only* in the north; which shews it to have been then the prevalent opinion, that they appeared most frequently in that quarter. Αλλα μὴν οὐδὲ τὸ τοῦ ἀληθούς, ὅτι ἐν τῷ πρὸς ἀρκτὸν τοπῷ γίνεσθαι ἡ Κομήτης μόνον. So likewise PLINY (lib. II. c. 25.) Xiphias, Dilceus, Pitheus-doliogorum cernuntur figura, in concavo fumidæ lucis. Ceratias. Lampadias. Hippeus. Candidus Comètes. Omnes ferme *sub ipso septentrione*, aliquâ ejus parte non certâ, sed maxime in candidâ, quæ lactei circuli nomen accepit. And SENECA (Quæst. Nat. lib. VII.) Placet ergo nostris, Cometæ, sicut Tubas, Trabeſque, et alia ostenta cæli, denſo aëre creari. Ideo *circa septentrionem frequentissimè apparent*, quia illic plurimum est aëris pigri.

fluid being more divided in more resisting air. But as those masses of electricity, which move where there is scarcely any resistance, so generally affect the direction of the magnetic meridian, the ideas which have been entertained of some analogy between these two obscure powers of nature, seem not altogether without foundation*.

If the foregoing conjectures be just, distinct regions are allotted to the electrical phænomena of our atmosphere. Here below we have thunder and lightning, from the unequal distribution of the electric fluid among the clouds; in the loftier regions, whither the clouds never reach, we have the various gradations of falling stars; till beyond the limits of our crepuscular atmosphere the fluid is put into motion in sufficient

* It appears to me more rational to resolve this analogy into a power of electricity to influence magnetism, than into a supposed similarity of two fluids; as the former can be made evident by our artificial experiments, but there is no proof of the latter. When fire-balls, therefore, are said to affect the magnetic meridian, I do not mean that they are drawn in that direction because it is the line of magnetism, but rather that the magnetic poles of the earth are thrown into their present position, by the accumulation and action of that very electricity upon which the fire-balls depend. Should a change be produced by any cause in the place of this accumulation, or the state of its motion, it is not improbable, that the main polarity would be given to other portions of the earth, whence a variation in the pointing of the compass would necessarily ensue. If Dr. FRANKLIN'S hypothesis be admitted, ascribing the electrical state of the polar atmosphere to the crust of ice (a bad conductor) in those regions, it follows, that should ice form or be collected in one part more than in another, the atmosphere there would become more highly electrical, and, in so far as the magnetism is given by electricity, the adjoining portion of the earth would acquire a stronger polarity. Now it is certainly worthy of remark, that since our first northern navigations, the coast of West Greenland and its surrounding seas have become gradually more and more inaccessible on account of ice, and that the magnetic needle all this time has been constantly changing its variation to the westward.

masses

masses to hold a determined course, and exhibit the different appearances of what we call fire-balls; and probably at a still greater elevation above the earth, the electricity accumulates in a lighter less condensed form, to produce the wonderfully diversified streams and coruscations of the *aurora borealis*.

I have the honour to be, with the greatest respect,

S I R,

Your most obedient humble servant,

C. BLAGDEN.

END OF PART I. OF VOL. LXXIV.